# Description of Monts Doudou, Gabon, and the 2000 Biological Inventory of the Reserve

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This study highlights the urgent need to map biodiversity. Given the current levels of world habitat loss and continued high rates of deforestation, a biodiversity map is essential for effective conservation practices. In basic sciences, this map is needed to understand the complex historical factors that have shaped the origin and evolution of life. Now is the time to document and analyze biodiversity before the chance is forever lost.

This volume presents the results of a biological inventory conducted in Monts Doudou (Doudou Mountains) located in southwestern Gabon in the Gamba Complex of protected areas (Fig. 1). Seven scientists participated in the field inventory, which took place in 2000. This chapter briefly describes the Monts Doudou region, the organization of our 2000 field season in the region, geology, climate, and weather conditions during the expedition.

The Gamba Complex (1°50′–3°10′S; 9°15′–10°50′E) is the largest protected area in Gabon covering 11,320 km$^2$ bordering the Atlantic Ocean and extending up to 100 km inland. This region is one of the Congo Basin's most diverse in terms of habitats. Starting with the coast, they include beach and dunes, littoral forest, mangrove forest, coastal scrub forest, freshwater swamp, lowland seasonally flooded forest, upland non-flooded forest, open grassland and extensive lagoons and lakes adjacent to the ocean. Further inland—the location of the present study—are extensive tracts of upland forest dissected by lowland, seasonally flooded forest along rivers and streams. World Wide Fund for Nature (WWF) identified three global ecoregions in the Complex: Atlantic Equatorial Forest, Guineo-Congolian Coast Mangroves, and the Western Congolian Forest-Savanna Mosaic (Olson and Dinerstein 1998).

The Complex is currently divided into multiple zones with varying degrees of protection:


FIGURE 1. Localisation de l'Aire d'Exploitation Rationnelle de Faune des Monts Doudou.

- l'Aire d'Exploitation Rationnelle de Faune (AERF) de Moukalaba-Dougoua (decree number 1484/MEF/SF-5225 of 17 November 1962) comprising the Réserve de Faune of Moukalaba-Dougoua and the Domaine de Chasse of Moukalaba;

- l'Aire d'Exploitation Rationnelle de Faune des Monts Doudou (decree number 000105/PR/MEFR of 28 January 1998). The relief is uneven and ranges to 700 m in elevation.

- l'Aire d'Exploitation Rationnelle de Faune de Setté Cama (decree number 1487/SF-4225 of 17 November 1962 and decree number1571/SF-CHPP of 29 December 1966) comprising the Réserve de Faune of Petit Loango, the Réserve de Faune of Plaine Ouanga, Domaine de Chasse of Setté Cama, Domaine de Chasse of Ngové-Ndogo and Domaine de Chasse of Iguéla.

The study was concentrated in the AERF de Moukalaba-Dougoua and AERF de Monts Doudou.

**Transect Sites**

This study included three elevations along the eastern slope of Monts Doudou: forest at the lowest elevation (110 m), mid-elevation (375–425 m), and the summit zone (585–660 m). The following three sites were inventoried:

110 m (Camp 1) - Province de Ogooué-Maritime, Reserve de Faune de la Moukalaba-Dougoua, 12.2 km 305° NW Doussala, 40.2 km 324° NW Mourindi, 2°17.00'S, 10°29.83'E, 110 m, lowland rain forest, 24 February–4 March 2000.

350–425 m (Camp 2) - Province de Ogooué-Maritime, Aire d'Exploitation Rationnelle de Faune des Monts Doudou, 24.3 km 307° NW Doussala, 52.1 km 321° NW Mourindi, 2°13.35'S, 10°24.35'E, 350–425 m, mid-elevation rain forest, 5 March–12 March 2000.

585–660 m (Camp 3) - Province de Ogooué-Maritime, Aire d'Exploitation Rationnelle de Faune des Monts Doudou, 25.2 km 304° NW Doussala, 52.6 km 321° NW Mourindi, 2°13.63'S, 10°23.67'E, 585–660 m, mid-elevation rain forest, 14 March–21 March 2000.

**Itinerary of the 2000 Expedition**

Reconnaissance (6–16 February 2000) was conducted by Fisher to determine the route for the elevational transect. Monts Doudou was accessed through the village of Doussala, which is accessible by vehicles via the Tchibanga-Moabi road and then north by road to the villages of Mourindi and then Doussala. Since maps indicating the major peaks of the reserve were not available, Fisher traversed 75 km through the reserve, exploring the highest reaches. Camp 3 at 660 m was the highest peak encountered within the protected area. Over the past 40 years, selective logging has occurred at several locations of the Gamba Complex, though much of the area explored during the reconnaissance was undisturbed. The network of abandoned forestry roads, however, provided access to Camps 1 and 2. Local help was hired from Doussala to prepare the road and bridges to Camps 1 and 2.

The vertebrate survey team was in Monts Doudou between 24 February and 21 March 2000. The botanical crew conducted its work from 16 March–27 September 2000 and the small mammal team conducted its population study adjacent to Camp 1 from April–October 2000. See Appendix 1 for a complete list of research participants.

## Geology

The geological formation in the Gamba Complex dates to the Quaternary. The region consists of the two principal soil types found in Gabon: coastal sediment and terrestrial crystalline soils. The Monts Doudou Reserve is situated at the limit of the sedimentary basin with a large part of the surface in the Mayombe mountain chain. The Mayombe chain extends 450 km long and 30 km wide, is 2.7 million years old and consists of three series from the base to the summit:

- Doussa series: migmatite, metasomatic granite, septa of metamorphic rocks (thin granular of gneiss);

- Kouboula mountain chain series: metamorphic series of quartzite and mica-schist with granitization;

- Douigni series: metamorphic series of mica-schist, amphibole-schist, quartzite (200 m thickness) with some intercalation of basic metavolcanit (talc-schist, epidotes) in the lower part and locally of acidic metavolcanit in the upper part: tufa, porphyroïds (metarhyolit) (MENIPN 1983).

The most recent section dates from 2.7 to 1.7 million years and includes conglomerates, arkose, quartzite and chloro-schist (MENIPN 1983). Near the village of Digoudou, on the North of Nyanga; the particular geology of the site is reflected by spectacular extrusions of metamorphic rocks derived from limestone or from dolomites often veined by a variety of colors.

**Soil**

The pedology of the Gamba Complex is characterized by ferralitic and hydromorphic soil. From the coast to the hinterland, ferralitic soils predominate in the coastal sedimentary basin, characterized by their lower topographic position and under the influence of the water table. Their texture is sandy clay (20–30% argil) to clayey sand (30–45% argil). In the inundated forest, the soil is composed of sulfur material near the surface. The swampy plants accumulate pyretic materials on the roots and when the soil desiccates, oxidation produces sulfuric acid resulting in a pH of 3.0 to 3.5. In areas where the soil is regularly subjected to floods, a lateritic layer could develop at a depth equal to the water table. (Environmental Resources Management 1999).

The forest soils are covered by a thin layer of organic material that is reduced as the degree of humidity increases. In the savannas, the organic layer is less developed and could even be removed by erosion. The mineral surface possesses a thin epipedon resulting from the organic layer of sandy particles. The soil horizons are gray pale or ochre in color (Environmental Resources Management 1999).

In Monts Doudou, the soils have a higher rate of argil (60%) and although they are not deep, they represent the richest soils of the Gamba Complex. Sensitive to erosion, they are protected by the vegetation cover. On each side of the Moukalaba River, the savanna overlying limestone-schist is situated in the peneplain at 100 m altitude, subject to karstic evolution and rising of the water table during the rainy season. They are not particularly suitable for agriculture (MENIPN 1983).

As throughout Gabon, the mineral content of the soils found in Monts Doudou is poor and their structure fragile. The soils are susceptible to erosion and rapidly lose their nutrient elements after slash and burn agriculture.

**Hydrology**

The occurrence of surface water in the natural habitats makes an important contribution to species richness and ecosystem diversity in the Gamba Complex. The hydrology network of the Gamba Complex is divided into three principal watersheds: the Nyanga River, the Ndogo lagoon, and the Ngové lagoon. Monts Doudou is drained by the Ndogo watershed and by the Nyanga, which is the largest river in Gabon. The Nyanga drains a watershed of 22,500 km$^2$, of which 80% is situated in Gabon. The river enters Monts Doudou at its confluence with the Moukalaba 110 km from the Atlantic Ocean. Thereafter, a series of rapids and waterfalls marks its route for a distance of 40 km — as far as Igotchi. After Igotchi, the Nyanga snakes across the alluvial littoral formation in the mangrove zone for a distance of 55 km before reaching the ocean (MENIPN 1983). In Monts Doudou, the secondary water routes of the Nyanga watershed are the Mingandou, Yara, Dugungu, Bidugu and Mbani rivers. The Bidugu River forms the boundary between the lands of the Batsiengui and Moubaoulaou villages, while the Mbani River forms the boundary between the Digoudou and Moruindi villages. The principal lakes, which support fishing, are Tsougou Natsougou, Kambela, Mingangandou, Mibundzi, Mirobou and Munumboumba.

The Ndogo lagoon has a surface area of 733 $km^2$ and drains a watershed of 1,587 $km^2$. Rembo Ndogo (Ndogo River), the principal tributary of the Ndogo lagoon, is the second largest watercourse in Monts Doudou and drains a surface area of 412 $km^2$. The other watercourses of Monts Doudou that exit into the Ndogo lagoon watershed include the Doudou, Moukiama, Doufoucou, and Bibanga rivers.

## Socio-Economic Environment

Inside the Gamba complex, there are 0.8 inhabitants per km2, distributed in 35 villages and the city of Gamba (MPEAT 1993; Blaney et al. 1997; Blaney et al. 1998; Blaney et al. 1999; Mboumba Mavoungou et al. 1999). If the city of Gamba is excluded, the population density is only 0.2 inhabitants/km2. The rural communities are migrant populations established in successive waves between the 18th and the end of the 19th century (MENIPN 1983). The primsary ethnic groups found in the Complex originated in the Congo.

The Vilis, whose migration path is somewhat older, clashed with the Nkomis at the end of the 17th century and at the beginning of the 18th century. One part of the ethnic group established itself along the Atlantic coast. The Lumbus, from the Pointe-Noire region, divided into two branches, thereafter encountering the Vilis. The Punus migrated to the Ndendé sector, then returned towards Mouila and were diverted towards Mayombe. Pygmy populations are absent in the Complex even though they often preceded the Bantu people in their migrations (MENIPN 1983). The local populations practice agriculture, hunting, fishing, and forest products gathering for medicine and other needs (construction, palm wine, etc.)

Six villages are located in the Monts Doudou region: Mourindi, Moukoualou, Batsiengui, Boutembi, Igotchi and Digoudou. While the first five villages are located on the periphery of the protected area, Digoudou is located in the middle. The total number of inhabitants recorded in these 6 villages is about 600. Subsistence of the local population is intimately linked to natural resources such as wild animals and forest products. Gathering forest products requires journeys of up to 15 km (Blaney et al. 1998). The principal diet is based on agricultural products, principally plantain bananas, cassavas and manioc, sweet potatoes, corn, and yams. Every dry season, for a period of approximately two weeks, the people of Moukoualou and Mourindi fish in the meres situated in the Domaine de Chasse of Moukalaba and in the AERF of Monts Doudou (Blaney et al. 1998). Monts Doudou is additionally exploited for economic issues by a forester based near Igotchi who exploits the forest on the basis of a permit that expired in 1999.

## Meteorology

### Climate

Monts Doudou region receives a high level of solar radiation because of its proximity to the equator. The climate is hot and humid. The temperature varies between 17°C and 23°C in the dry season and between 25°C and 32°C in the wet season, with highest temperatures usually occurring between March and May. The climate is characterized by four distinct seasons:

a rainy season from September to December;
a short dry season of around one month duration between December and February;
a rainy season from February to May;
a dry season from June to September, during which there is extensive cloud cover.

The available data on precipitation for the last 10 years are from the Rabi and Gamba petrol stations operated by Shell Gabon (Figs. 2, 3). Given the short time frame of data collection, a robust analysis of average annual precipitation is not possible. However, the greatest rainfall in the last 10 years was observed in 1977 (2966 mm in Gamba and 2851 mm in Rabi). The driest years during the same 10-year period were in 1993 for Gamba (1615 mm) and 1992 for Rabi (1476 mm). According to the classification of climates by Koppen modified by Trewartha, Monts Doudou is situated in the humid tropical climate of type Aw defined by the alternation of rainy and dry periods with a rainy season during the austral summer (Money 1982). During the rainy season, convection currents can establish thunderclouds 10 km in diameter with a duration generally not exceeding 1 to 2 hours (Shell Gabon 1993). The force of these currents may uproot trees.

The rate of annual evaporation in the study area is around 1200 mm (McGregor and Nieuwolt 1998), which corresponds to half the annual precipitation and reflects the important role of relative humidity (Table 1). Temperature is uniform throughout the year with the coolest months during the dry season.

For 80% of the time, wind speed at Gamba is never greater than 5 m/s and direction is usually from the southeast (Shell Gabon 1993), with occasional winds from the south and southwest. They correspond to the trade wind, which drives the Benguela Ocean current along the coast towards the equator and is the principal cause of sand deposition along the coast. Although no weather data is available further inland, wind force seems to be reduced with distance from the coast.

TABLE 1. Average monthly temperature and relative humidity.

| Month | Temperature (°C) | Relative humidity (%) |
|---|---|---|
| January | 26.3 | 87 |
| February | 26.5 | 86 |
| March | 27.0 | 86 |
| April | 27.1 | 86 |
| May | 26.2 | 87 |
| June | 23.8 | 85 |
| July | 22.4 | 84 |
| Augurst | 22.8 | 90 |
| September | 23.9 | – |
| October | 25.0 | – |
| November | 25.3 | – |
| December | 25.7 | – |
| Annual | 25.2 | 86 |

Source: Lemoalle and Albaret 1995

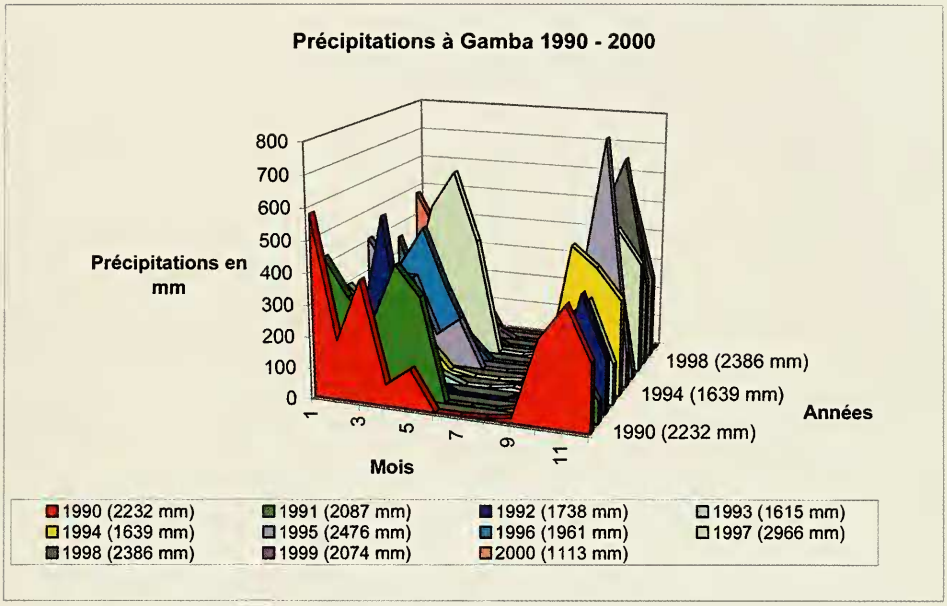



FIGURE 2. Précipitations à Gamba de 1990 à 2000.

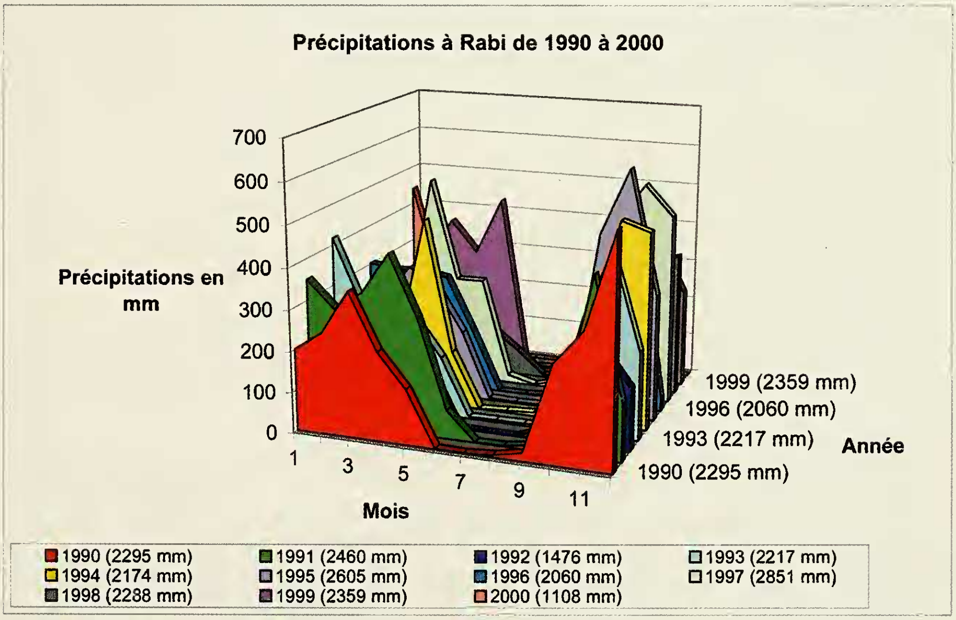



FIGURE 3. Précipitations à Rabi de 1990 à 2000.

**Meteorological parameters related to orography**

One of the principal abiotic factors influencing variation along elevational gradients is a shift in meteorological parameters related to orography (Riehl 1979). These factors include rain shadows, zones of higher rainfall and decreased solar radiation associated with regular cloud caps, and shifts in daily temperatures (Pendry and Proctor 1996). In turn, variation in these factors regulate water supply — drought or water logging, decomposition rates, soil nutrients, etc., and these parameters have direct bearing on environmental complexity and ecological productivity (Rosenzweig 1992).

Little information is available from the Congo Basin region on variation in climatological variables along mountain slopes. Further, since one of the goals of our Monts Doudou inventory was to examine biotic changes related to altitudinal variation and the fact that the activity patterns of many of the surveyed organisms are directly related to factors such as rainfall and temperature, meteorological information was gathered during the course of the February–March 2000 biological inventory of Monts Doudou to address these points.

Meteorological data collected included daily minimum and maximum temperatures, using a min-max thermometer, and precipitation, using a standard rain gauge. These devices were installed within a few hours of arriving at each campsite. The rain gauge was placed in an open area without canopy cover and the thermometer attached to the trunk of a

TABLE 2. Summary of minimum and maximum temperatures and precipitation during the 1999 expedition to Monts Doudou. Meteorological information was also obtained at the 110-meter site during the same period as the 350-meter and 625-meter sites.

| Periods of measurement within each transect | Temperature (°C)[1] Minimum | Maximum | Rainfall[2] (mm) |
|---|---|---|---|
| **24 Feb.–4 March** | | | |
| 110 m | 10, 20–24 | 10, 28–29 | 6, 25–22.5 |
| | 22.0 ± 0.33 | 28.2 ± 0.15 | 7.4 ± 2.89 |
| **5–13 March** | | | |
| 350 m | 9, 20–22 | 9, 24–27 | 4, 3–45.0 |
| | 20.9 ± 0.20 | 26.3 ± 0.33 | 9.8 ± 5.25 |
| 110 m | 6, 21–24 | 6, 25–30 | 2, 95–11.7 |
| | 22.3 ± 0.42 | 28.3 ±0.71 | |
| **14 – 22 March** | | | |
| 625 m | 9, 18–22 | 9, 24–26 | 6, 1.0–80.0 |
| | 20.1 ± 0.39 | 24.9 ± 0.26 | 14.3 ± 8.85 |
| 110 m | 9, 22–24 | 9, 27–30 | 2, 12.7–19.4 |
| | 22.9 ± 0.32 | 28.8 ± 0.33 | |

[1]Data are presented as number of records, range, mean, and ± standard deviation.
[2]Data are presented as number of days with rain, range, mean, and ± standard deviation.

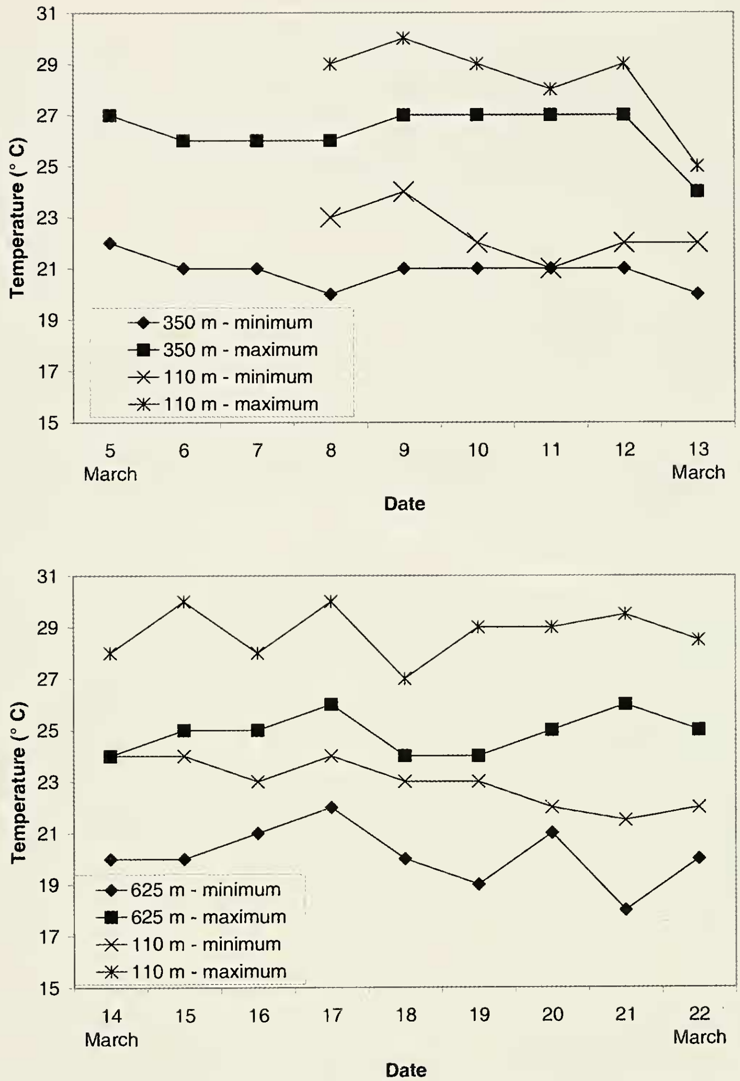
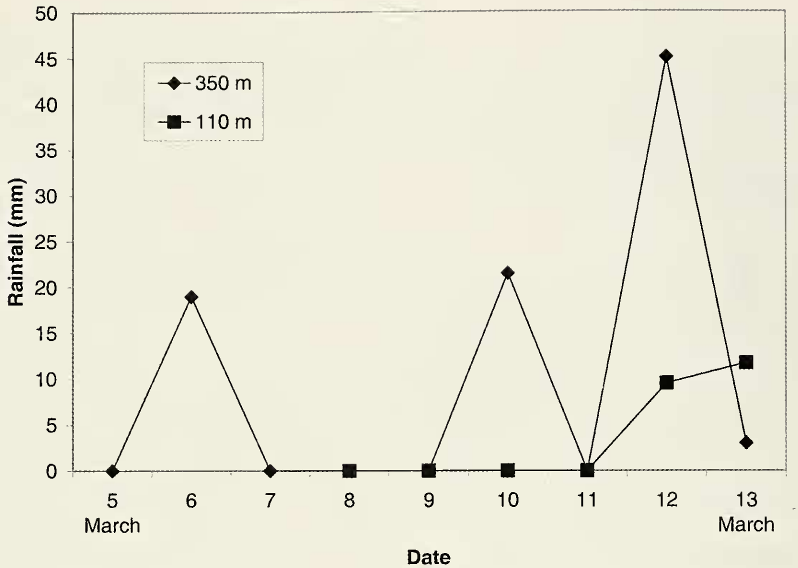



FIGURE 4. Comparison of minimum and maximum average daily temperatures during simultaneous periods in the 110 and 350 m zones (a) and 110 and 625 m zones (b)

tree (without epiphytic growth) in the shade. Readings were made each morning between 8:30 and 10:00 a.m.

Within a few days after our departure from the 110-meter site the research group of Marc Colyn installed a weather station adjacent to our joint study area within that elevational zone. Data from this station, which were obtained by Violaine Nicolas during the period we were at higher elevations, allows comparison of simultaneous weather patterns on the mountain between different elevational zones.



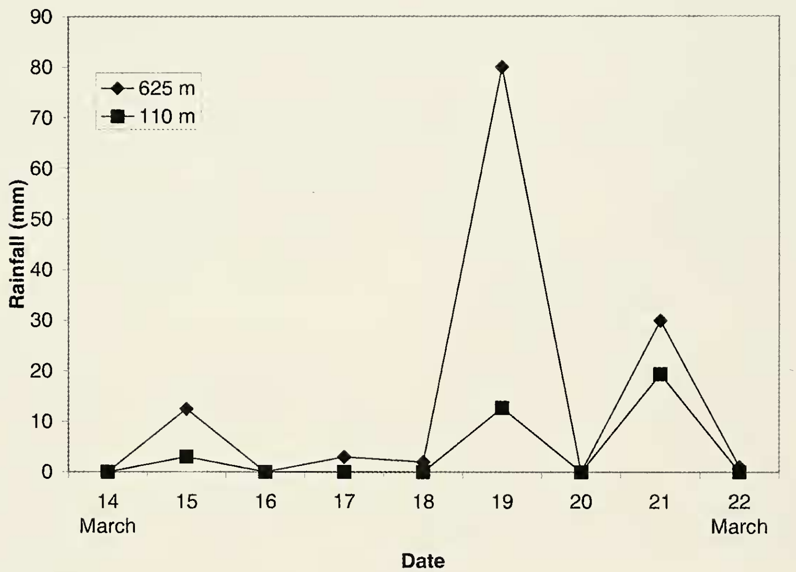




FIGURE 5. Comparisons in daily rainfall during simultaneous periods between the 110 and 350 m zones (a) and 110 and 625 m zones (b).

## Variation along elevational gradient

There was a clear decrease in the minimum daily average temperature with increasing altitude from 22.0°C at 110 m to 20.1°C at 625 m. Further, the average maximum temperature was higher at the lowest elevation and decreased with altitude from 28.2°C at 110 m to 24.9°C at 625 m (Table 2).

The pattern of increasing average minimum and maximum temperatures during the period of the inventory, from 24 February to 22 March, was established for the 110-meter contour. The maximum average daily temperature at 110 m was 28.2° C between 24 February and 4 March, 28.3° C between 5 and 13 March, and 28.8° C between 14 and 22 March. The same pattern holds for average minimum temperature. Thus, during the course of this field trip there was a slight increase in daily temperatures within a single elevational zone. The factors of altitude and season played a role in measured changes in weather patterns. However, during the four weeks we were in the field the shift in average minimum and maximum average temperatures was greater between elevational zones than the seasonal shift at the 110-meter site.

The number of days of rainfall between elevational zones was rather consistent, with precipitation occurring 44-67% of the days we were at each site (Table 2). However, the average number of millimeters per rain shower, as well as the maximum amount during any 24-hr period, increased steadily with altitude. Total rainfall was 74.0 mm at 110 m (24 February to 4 March), 88.5 mm at 325 m, and 128.5 mm at 625 m. At 110 m the three most rainy 24-hour periods were 22.5, 22.0, and 14.5 mm, at 350 m 45.0. 21.5, and 19.0 mm, and at 625 m 80, 30, and 12.5 mm. In general most of the showers occurred in the later portion of the day, evening or night. Only on a few occasions did we experience rain during the morning or early afternoon.

**Variation along the slopes of Monts Doudou**

Data obtained from the meteorological station at the 110 m site while we surveyed higher elevations provide a means to understand how weather patterns vary along the slopes of Monts Doudou. The data from the 110 m zone were separated according to the periods that we were working at the 350-meter and 625-meter zones (Table 2). Average minimum and maximum daily temperatures were higher at 110 m than in the 350-meter zone (Fig. 4a) and the 625-meter zone (Fig. 4b).

Twenty-four hour periods with rainfall at the 110-meter and 350-meter sites between 5 and 13 March showed few parallels (Fig. 5a). No rain fell at the former site until the end of this period, while at the latter there was precipitation at least every other day. This is in contrast to the 625-meter and 110-meter sites between 14 and 22 March, which showed coinciding periods of rainfall, although the magnitude was always less in the 110-meter zone (Fig. 5b).

Thus, rain showers reaching the mountain tend to deposit more precipitation at higher altitudes. Sometimes these systems are widespread and at other times rather isolated. Even though there was some seasonal change in temperature during the period of our inventory, the most notable shift was related to elevation. On the basis of the meteorological data gathered it is clear that an altitudinal deviation of slightly over 500 m between the lowest and highest survey sites on Monts Doudou shows important differences in weather patterns and in turn differences could be expected in the biotic communities along this elevational gradient.

## Ackowledgments

We are grateful to Violaine Nicolas for obtaining and allowing us to use the weather data she obtained in the 110-meter zone.

## Appendix 1

### Participants in the Project (Field and Laboratory)

A total of 16 field workers and scientists took part in this multidisciplinary study, including field participants as well as researchers participating in the analysis of collections. The names and addresses of all scientific participants follow:

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